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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Improving the Lubrication of Gas Engines

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FOR ALL GAS ENGINES

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Improving the Lubrication of Gas Engines

GOOD lubrication of a gas engine implies reasonable freedom from wear and carbonaceous deposits. To bring about this desirable condition, more than the correct application of the proper lubricant is required. Air and gas entering the engine must be free from injurious substances and mixed in the proper proportion. The mixture must be fired at the right moment and the heat generated carried away by efficiently operated cooling and exhaust systems. The modern gas engine is a well designed and sturdily constructed machine, and if the operator keeps the load and speed within the range for which the engine was designed, carefully controlling the conditions just enumerated, good lubrication should result.

The January, 1937 issue of "LUBRICATION" described the fundamentals of gas engine lubrication—this article is chiefly a discussion of the many related maintenance problems.

Application of Lubricant

The preferred method of assuring a continuous film of lubricant between all rubbing parts is the delivery under pressure of a controlled quantity of oil to such surfaces. Slow-speed engines, when load conditions are not severe, can be satisfactorily lubricated by gravity flow or splash, but high-speed, heavy duty gas engines should be equipped with forced feed lubrication to all surfaces subject to wear.

In the conventional systems oil is picked up from the sump in the engine base by the oil pump discharging through an oil filter and an oil cooler to the oil manifold, thence to the main bearings and through the shaft to the connecting rod bearings. Other bearings, gears and auxiliary parts either receive oil under pressure from the oil manifold or by splash. Cylinders are lubricated in small engines with oil thrown from the crankpin bearings and in larger engines by a separate cylinder lubricating oil pump. A separate feed for cylinder lubrication is very desirable, permitting the use of different lubricants for bearings and cylinders.

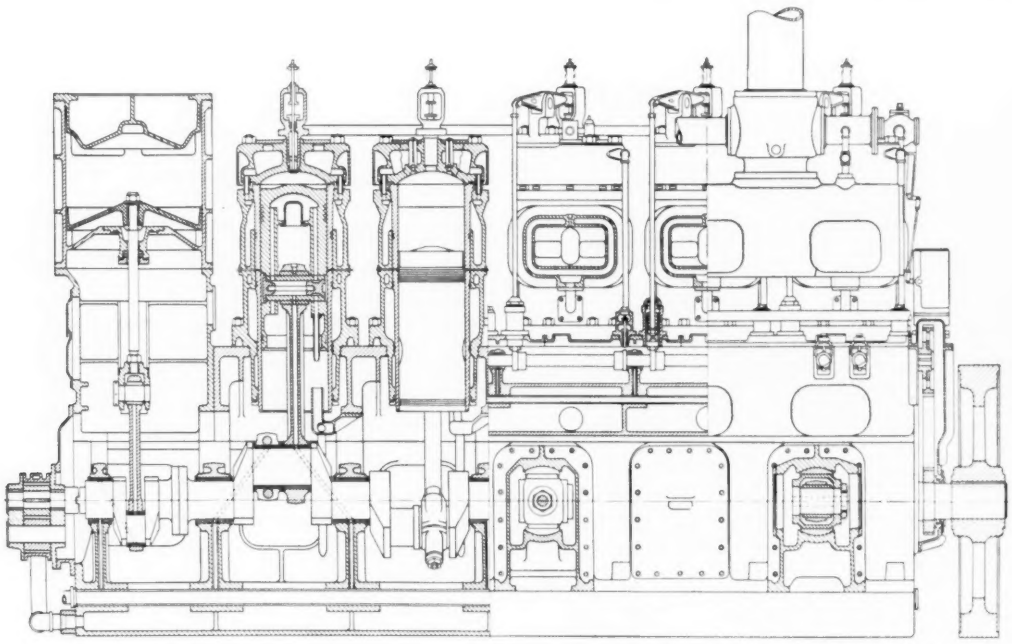
Oil Quantity Control

The engine should be examined periodically to determine whether all parts are receiving the correct amount of oil. In this connection the overall oil consumption of the engine is a good guide. This involves checking for oil leaks which includes observations of the water discharged from the oil cooler and the centrifuge. Oil lost through any reclaiming process, which may amount to 5% of the oil reclaimed, should, of course, be deducted from the engine oil consumption. After eliminating all other losses, the amount of oil passing by the piston rings should not exceed one gallon for every two thousand rated horsepower-hours operation. Sufficient lubrication can usually be obtained with an overall oil economy of only four thousand rated horsepower-hours per gallon. The correct cylinder feed should be measured in rated horsepower-hours per gallon rather than in drops per minute, since the latter

figure is affected by oil viscosity and temperature and also by the specific gravity of the oil in hydrostatic lubricators.

Evidences of excessive cylinder lubrication are carbon deposits and surplus oil in the exhaust ports.

Insufficient oiling is indicated by dry spots on the cylinder walls and by excessive wear. Ring wear can be noted by the enlargement of the ring gap, while a ridge at the top of the ring travel will serve as a guide as to the amount of cylinder wear. Normal top ring wear in gas engines is equivalent to a gap increase of .001″ per inch of ring circumference in 2,000 hours in four-cycle, and in 1,000 hours in heavily loaded two-cycle engines. Cylinders normally wear .001″ or .002″ per 1,000 hours, depending on whether four- or two-cycle. In large engines ring gaps of .250″ and cylinder wear of .050″ are permissible before replacements are necessary. These figures are for guidance only and will vary considerably with different designs and operating conditions.



Courtesy of Worthington Pump & Machinery Co.

Fig. 1—Vertical Gas Engine.

After the degree of cylinder lubrication is ascertained, the rate of cylinder feed should be corrected so that the overall oil economy is normal, that is, assuming that the leads to the cylinder are located at the lower end of the ring travel, which is the usual location.

If leads are located about 12″ apart at the top of the ring travel, as is desirable in high output 2-cycle engines, then the cylinder feed should approximate 5,000 h.p. hours per gallon regardless of the overall economy. The reason the leads are located at the top in two-cycle engine cylinders is that crankcase oil has difficulty getting by the ports, also, the intense heat generated makes it desirable to inject the lubricant at the point of maximum wear. This, of course, requires the use of a timed lubricator, but rather than go to this expense, either bi-metallic or sealed joint piston rings are often installed to take care of a serious ring or cylinder wear problem. Dirt, improper cooling, excessive piston clearance, high exhaust back pressure and improper lubricant can also contribute to a high rate of ring or cylinder wear.

In the trunk type engine, the amount of oil reaching the cylinder walls is influenced by the amount of connecting rod clearance. This can be roughly checked when the engine is stopped by moving the connecting rod with a bar. Bearing clearance can also be judged by noting the oil pressure when the engine is idling. Tight bearings may also be detected if the engine comes to a quick stop when the ignition switch is closed. The connecting rod bearing clearance (new) should be about .001″ per inch of crankpin diameter and should be readjusted before wear increases the clearance to .003″ per inch. Bearing end clearance also governs the quantity of oil splashed. Failure to check the connecting rod bearings approximately every 4,000 hours will frequently lead to high oil consumption.

The operator has recourse to several means of controlling oil consumption other than maintaining the oil level at the correct height. The amount of splash is definitely proportional to the oil pressure and most engines, except where pistons are oil cooled with bearing oil, will operate under a fairly large range of oil pressures, thus providing a ready means of oil consumption control. Almost any degree of oil consumption can also be obtained with the wide variety of efficient oil control rings now available. Oil viscosity, which is merely a matter of selection of the proper grade of oil, and oil temperature which determines the actual viscosity of the oil in the engine, are important factors affecting oil consumption.

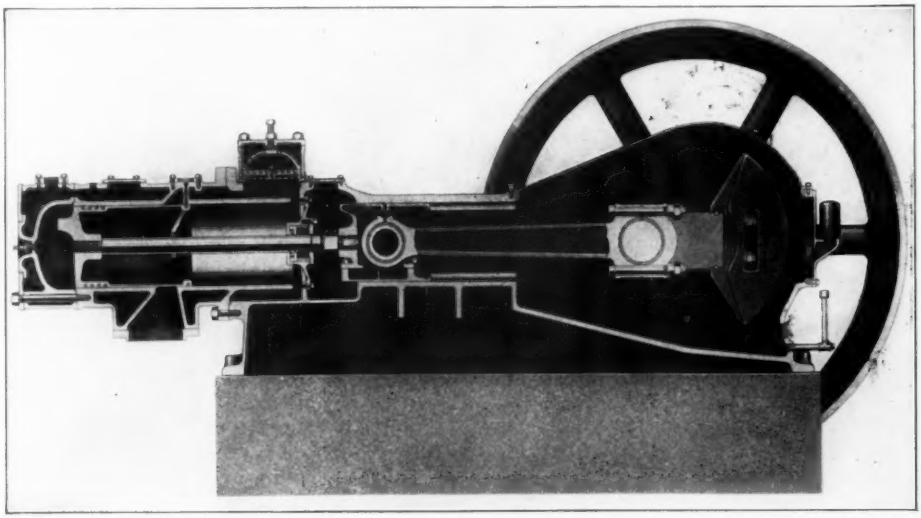
Engines which are stopped frequently for several hours, during which time the oil drains from lubricated surfaces, should be equipped with an auxiliary hand pump for forcing oil to the engine prior to starting. Cold wiped bearings can result if this precaution is not taken.

Oil Quality

Cylinder oil for the gas engine should have sufficient body or viscosity (SAE 30 to 40) to properly seal the rings, prevent loss by compression, and contamination of the crankcase oil by blow-by gases which would cause sludge formation. In two-cycle engines the oil must have sufficient film strength and heat resistance to prevent ring and cylinder wear. A high degree of detergency or cleansing ability is not ordinarily needed in gas engines due to the clean burning character of the fuel.

Crankcase oil should be fairly light in viscosity (SAE 20 or 30) to provide adequate fluidity, high flow rate and proper cooling effect on the bearings. Since sludge formation is often a problem, crankcase oil should be resistant to oxidation. Crankcase oil also should be of the type which filters readily, permitting the removal of sludge-forming bodies from the oil by efficient oil purifying devices.

For the "one-shot" systems used for manually lubricating valve stems, a light oil (SAE 10) of low carbon residue is recommended. Gas compressors often use the same oil as the gas engine; however, if the gas which is being compressed contains liquid fuel, the lubricant should be compounded with perhaps 5% animal or vegetable oil which resists the washing action of the liquid fuel.



Courtesy of National Supply Company, Superior Engine Division

Fig. 2—Horizontal Gas Engine.

Gaseous Fuels

From an operating standpoint, the characteristics of the gas of greatest interest are: the heating value, the amount of air required for combustion, the anti-knock value, the preignition tendency, and the amount and nature of impurities. The average gas engine is designed and originally adjusted for a clean, natural gas, containing around 90% hydrocarbon gases such as methane, ethane, or ethylene, and 10% inactive gases such as carbon dioxide or nitrogen. Such a gas will have a heating value of about 1000 B.T.U. per cubic foot and will require approximately ten cubic feet of air per cubic foot of gas for complete combustion. The anti-knock value will be over 100 octane number and the fuel will not easily preignite. Such a fuel will permit a high compression ratio and maximum spark advance. In the combustion of this gas about 12 gallons

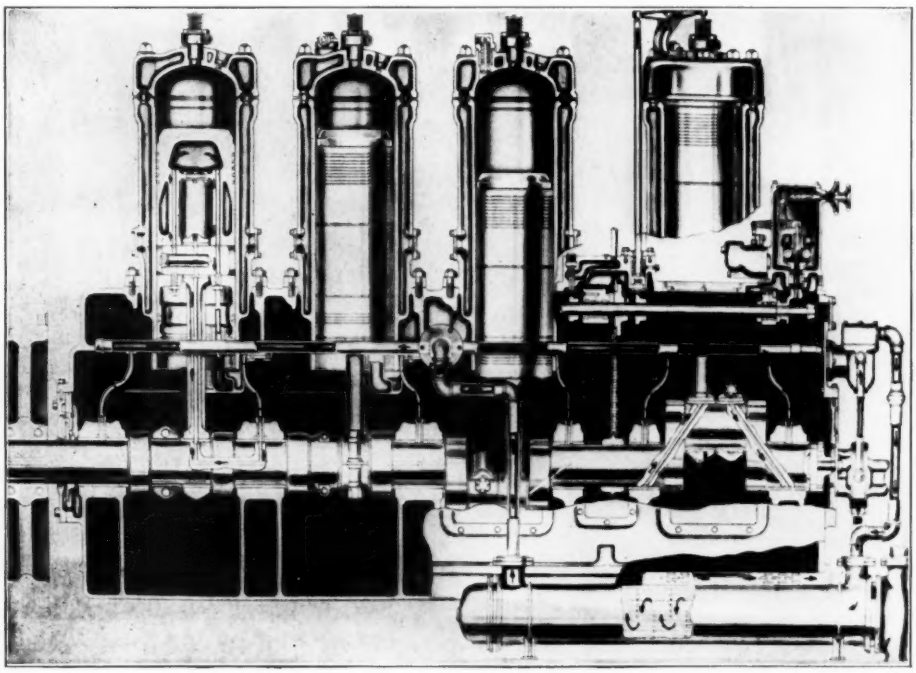
of water will be formed for every 100 horsepower-hours produced.

For the benefit of those more familiar with gasoline engine operation, gasoline vapors contain about 5600 B.T.U. per cubic foot, have an air/fuel ratio by volume of 60:1, an octane number of perhaps 70, and produce less than nine gallons of water per 100 h.p.-hours. Thus, the natural gas engine inhales a gas only about one-sixth as potent as gasoline vapors, but consumes nearly six times as much, so that the power output is about the same. The natural gas engine can utilize a higher compression ratio but produces over 30% more water in the exhaust gas than a gasoline engine.

In all probability the gas that an engine is using is considerably different than that on which the engine was originally tested. Usually the installation engineer makes such corrections and adjustments as necessary. However, when difficulties are encountered, a new analysis of the gas should be secured and the following points taken into consideration:

The proper air/fuel ratio by volume for a gas will roughly be about 1/100 of the heating value, thus a rich gas will require a leaner setting of the mixing valve than a gas of low heating value. Illuminating and coke-oven gas contain a high percentage of hydrogen which has a low heat value on a volume basis due to its low density. These gases may have a heating value of about 500. Producer gas and blast furnace gas contain a very high percentage of nitrogen and carbon monoxide and may have a heating value of 150. There are, in the United States, over 100 engines operating on sewer gas which contains about 75% methane and 20% carbon dioxide and has a heating value of about 600.

The amount of spark advance permissible without detonation will vary with the octane number. In decreasing order of octane number the more common gases are: methane, ethane, propane, ethylene and butane. Hydrogen has a great tendency to detonate and preignite unless a fairly high percentage of excess air is present. The presence of nitrogen and carbon dioxide, on the other hand, reduces the detonating tendency.



Courtesy of Clark Brothers Company, Inc.

Fig. 3—Path of oil through engine.

Water formation is of some importance where crankcase temperatures are low. The number of gallons of water formed per 100 horsepower-hours being: hydrogen 20, methane 12, and butane 9.

The type and character of undesirable products which may enter the engine with the fuel gas varies. Natural gas is comparatively clean; however, it may contain rust from deteriorated pipes or casinghead gasoline. Illuminating gas is also usually clean. Producer gas will contain soot and tarry matter. Blast furnace gas is very dirty, containing lime dust, iron oxide,

and soot. Coke-oven gas produced from bituminous coal contains coke-dust, tar and sulfur. Sewer gas may contain a very high percentage of hydrogen sulfide, usually removed by an "iron sponge." Impurities are often removed by scrubbing or water-washing the gas, in which case water may enter the engine with the gas. Neither the solid impurities nor the hydrogen sulfide content should be over 0.2% by weight, which is equivalent to 0.3 grains per cubic foot. Solid impurities may cause wear or gummy deposits in the engine. Hydrogen sulfide causes corrosion and preignition and also requires retardation of the spark to prevent detonation. Casinghead gasoline in natural gas may result in the over-production of power and an increase in detonation resulting in overheating.

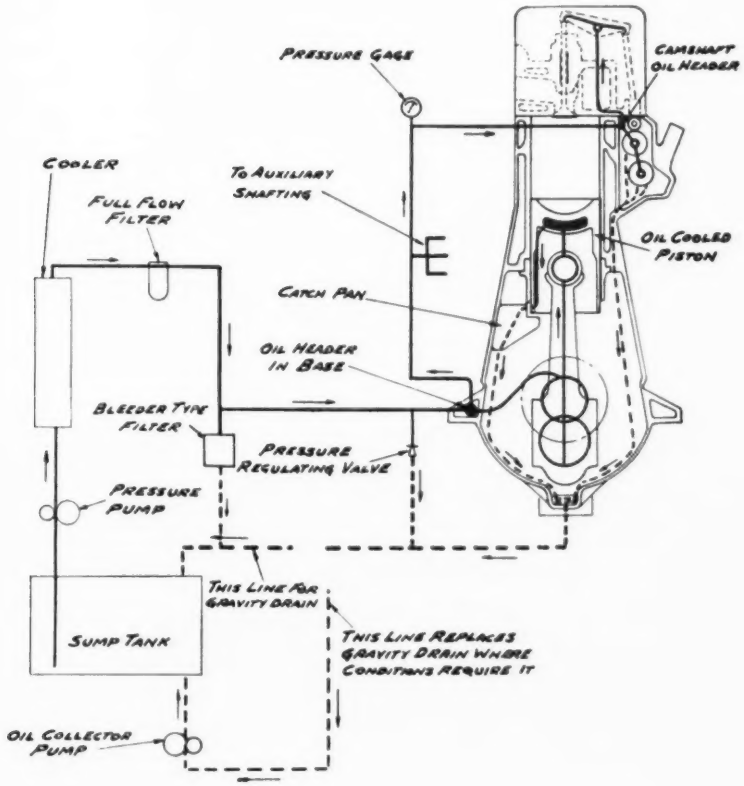


DIAGRAM OF TYPICAL LUBRICATING OIL SYSTEM

Courtesy of Cooper-Bessemer Corporation

Fig. 4

Butane as an Automotive Fuel

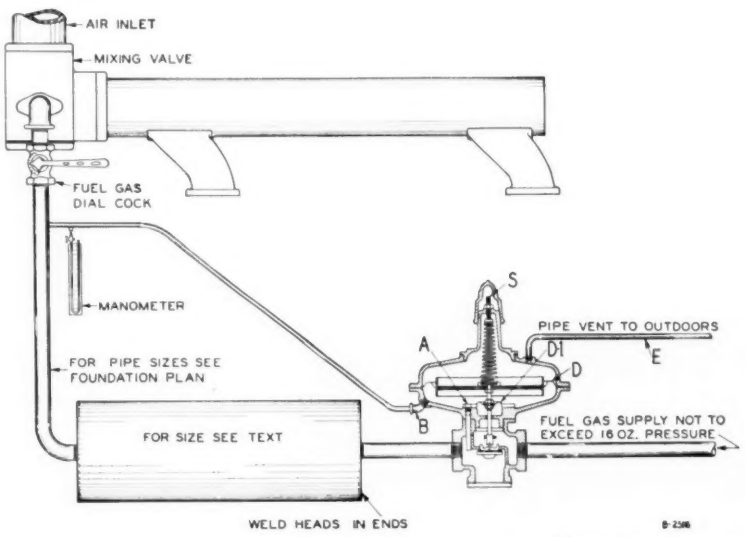
Butane has become a popular fuel for automotive service for several reasons: Butane is a rich gas containing nearly 3000 B.T.U. per cu. ft. and an engine requires only about one cubic foot for every 30 cubic feet of air. It is easily liquefied, normally boiling at atmospheric pressure at 32 degrees Fahr. and thus does not require an excessively high pressure to maintain the fuel in a liquid state. Due to the relatively low liquefaction pressure, containers are not unduly expensive. Butane is plentiful in localities surrounding oil refineries as a by-product in the manufacture of gasoline, frequently costing less than gasoline.

Butane contains 20% less B.T.U./gal. than the average gasoline and burns with the same efficiency at the same compression ratio; therefore in the same engine the fuel economy will be proportionately less than gasoline. But butane has a high octane number (93) which permits the use of a higher compression ratio at which a higher percentage of heat energy is converted to power. If the compression ratio is raised sufficiently, the fuel economy with butane will be nearly the same as gasoline at the lower ratio. Butane is, of course, carried under pressure which is reduced at the vaporizer from which the gas goes through a gas/air mixer which may be merely a modified carburetor. The efficiency of utilization depends largely on the functioning of the gas/air mixer; consequently a thoroughly practical device should be used.

The installation of high compression cylinder heads and the fuel adapter are about the only changes necessary in the engine to convert from gasoline to butane fuel. Valve timing is normal but the spark has to be readjusted. Advantages claimed for butane over gasoline operation are: Better performance at low speeds due to improved distribution, with about the same power developed at higher speed; a reduction in carbon deposits and less frequent oil change due to more complete combustion which also results in a cleaner exhaust with less carbon monoxide.

Fuel Systems

The proper proportioning of air and gas is highly important if good gas engine performance is to be obtained. Gasoline engines are confined to a rather narrow range of mixture ratios and if the mixture strength is reduced to 80%, mis-firing will occur. This is also true to a lesser extent of butane, but with methane and other gases, particularly those containing hydrogen or carbon monoxide, the mixture strength can be reduced on the lean side to perhaps 50% before mis-firing occurs. By operating at lean mixtures fuel consumption may be improved as much as 10% at part loads. Ordinarily, power considerations are of greater importance and for this reason gas engines should be operated slightly on the rich side near the maximum power ratio which occurs at about 15% rich. Operating with a mixture richer than that required for maximum power not only wastes fuel but causes over-heating, particularly of pistons, leading to ring sticking, sludging of oil and high ring or cylinder wear. Operating with very lean mixtures should also be avoided as it will promote late burning which may result in backfiring, burning of valves and excessive oxidation of the lubricating oil on the cylinder walls.



Courtesy of Ingersoll Rand Company

Fig. 5—Fuel System.

The correct air/fuel ratio varies with the type of gas from 30:1 with Butane, to 1:1 on blast furnace gas. Thus one of the major problems of the gas engine operator is the correct adjustment of the air/gas mixing valve.

A typical fuel system for a four-cycle gas engine consists of a primary and a sensitive gas pressure regulator, a gas reservoir and an air/gas mixing valve. The primary regulator reduces the gas pressure to between 1 and 2 inches of water, while the sensitive regulator brings it down between 0 and ½ inches of water. With most gases atmospheric pressure at the engine is desired; some weak gases, however, have to be induced in such quantity that a positive pressure of more than ½ inch of water is required.

After the pressure of the gas has been reduced, it passes through a gas reservoir or surge chamber to absorb pulsations from the engine. The reservoir should have at least eight times the displacement of one piston.

Finally between the gas reservoir and engine is an air/gas mixing valve for properly proportioning the mixture entering the engine. The mixing valve has two passages, one for air and one for gas. The quality of the mixture is adjusted by hand, by regulating the size of the gas port; while the quantity is controlled by the governor opening or closing both ports simultaneously.

To properly adjust the air/gas ratio a mercury manometer should be connected to the intake manifold for measuring the intake vacuum. The gas port opening should be adjusted slightly on the lean side of the setting for maximum manifold vacuum which represents the maximum power position. The correct setting should give a manifold vacuum about 5% less than maximum on the lean side. The setting will normally give best operation and also impose least duty on the lubricating oil.

In the two-cycle engines the gas is not mixed with the intake air since about 30% of the air is used for scavenging the cylinder and, therefore, this amount of gas would be wasted. In two-cycle engines the gas is first reduced in pressure to about fifteen pounds and is then mechanically injected directly into the cylinder. For engines operating at a constant load, as is usually the case, the governor only regulates the amount of gas injected and has no control over the air supply. For engines operating under variable load conditions, the air supply should also be automatically controlled by the governor, otherwise mixtures may be too lean at light loads, causing late burning and attendant ills.

Air/gas ratio will change with variation in the heat value of the fuel and also with changes in manifold vacuum produced by the gradual clogging of the intake air cleaner.

Spark Timing

Lubrication difficulties may be encountered if the spark is not timed properly. If too far advanced, maximum pressures will be high and detonation apt to occur. If retarded, late burning will result. In either event incorrect spark setting will cause overheating which will heat the lubricant unnecessarily and may result in cylinder or ring wear, carbonization or sludge.

The spark timing should be frequently checked and compared with the B.T.U. content of the fuel. As a general rule, the manufacturers recommended spark setting is for a gas of 1000 B.T.U./cu. ft. and the spark should be changed about one degree for each 100 B.T.U. variation from this figure, advancing the spark for the lower calorific value, slower burning fuels.

As a check on the spark timing, observe the exhaust temperatures which will be high if the spark is retarded. If advanced, the engine will run roughly and detonation may be audible. With the correct spark setting, indicator cards will show a maximum pressure at about 10 degrees past top dead center.

The correct spark setting also varies with the air/gas ratio. In a typical engine the correct spark advance is 30 degrees at the ideal air gas ratio and 40 degrees at a weaker mixture containing 70% of the ideal amount of gas. The importance of ignition timing is apparent when it is realized that a 10 degree change may increase maximum pressures by 100 lbs. or 20% with a corresponding increase in temperature and fuel economy reduced by 10%. Thus another good reason for keeping the air/gas ratio correctly adjusted is that otherwise the spark timing will be incorrect.

Cooling System

Efficient cooling is perhaps the most important engine factor that affects lubrication. Sludge, carbonization, wear, oil consumption, etc., are all dependent on engine temperature. Thus when any type of lubrication problem arises, engine cooling should be one of the first items checked.

As a rough figure, about 2500 B.T.U./B.H.P./hr. are removed by the cooling water. To prevent distortion of engine parts, the water temperature should not increase more than 10 degrees in passing through the engine. To meet this condition a circulation rate of 250 lbs. or 30 gallons per brake horsepower per hour is required. If the capacity of the water pump is much under this rate, the temperature differential will be excessive, and blow-by will result with the possibility of ring sticking and sludge formation.

Considerations which determine the proper water jacket operating temperature are numerous. For best power and economy 180 degrees is required. This temperature is recommended in small engines when the cylinder bore is not large enough to cause carbonization and where the oil is drained frequently so that the adverse effect of the higher temperature on the crankcase lubricant is not so important. Lower jacket temperatures are advisable for engines of large bore and oil capacity, not only to prevent lubrication difficulties but to avoid preignition or detonation. Jacket temperatures must not be too low, however, since at temperatures below 130 degrees water formation will cause cylinder wear at the lower end of the liner, and sludge in the crankcase. One prominent gas engine manufacturer recommends a water outlet temperature of 140 degrees, another 150 to 160 degrees. Taking all factors into consideration, it would appear that the most satisfactory jacket temperatures are 135 degrees in and 145 degrees out for large gas engines. The operator should not consider these recommendations as inflexible; if the gas used produces a large amount of water after combustion or contains hydrogen sulfide,

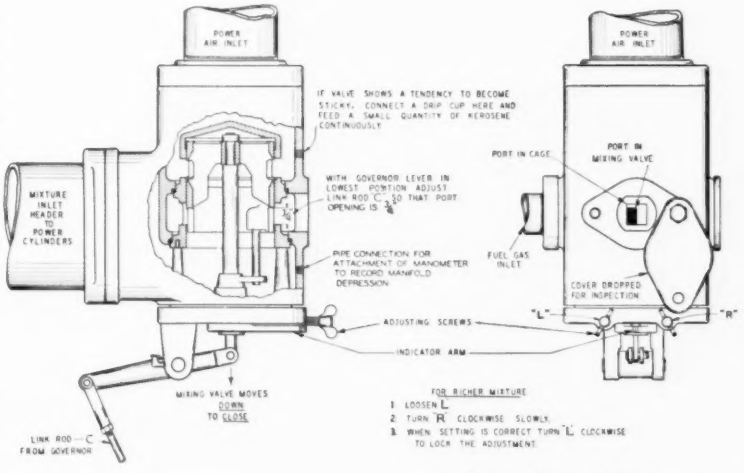

POWER AIR INLET
IF VALVE SHOWS A TENDENCY TO BECOME STICKY, CONNECT A DRIP CUP HERE AND FEED A SMALL QUANTITY OF KEROSENE CONTINUOUSLY
MIXTURE INLET HEADER TO POWER CYLINDERS
WITH GOVERNOR LEVER IN LOWEST POSITION ADJUST LINK ROD "C" SO THAT PORT OPENING IS 3/8
PIPE CONNECTION FOR ATTACHMENT OF MANOMETER TO RECORD MANIFOLD DEPRESSION
MIXING VALVE MOVES DOWN TO CLOSE
LINK ROD "C" FROM GOVERNOR
POWER AIR INLET
PORT IN CAGE
PORT IN MIXING VALVE
FUEL GAS INLET
COVER DROPPED FOR INSPECTION
"L"
"R"
ADJUSTING SCREWS
INDICATOR ARM
FOR RICHER MIXTURE
1. LOOSEN L
2. TURN R CLOCKWISE SLOWLY.
3. WHEN SETTING IS CORRECT TURN L CLOCKWISE TO LOCK THE ADJUSTMENT.

Fig. 6—Air Gas Mixing Valve.

Courtesy of Ingersoll Rand Company

higher temperatures may be desirable, while if the gas has a tendency to preignite, very low temperatures may be necessary.

To attain the recommended temperature of 135-145 degrees, a closed system using soft water is required with a by-pass arrangement so that some of the hot water discharge from the engine can be recirculated to the water inlet to the engine. If the load on the engine is usually constant, the water temperature control valve can be manually operated. Where the engine load fluctuates frequently, thermostatic control should be provided. It is much better to circulate a large quantity of warm water accompanied by a small temperature rise than a small quantity with a large temperature rise. In addition to reducing distortion, the faster water circulation lessens the possibility of sediment deposits in the water jackets and of steam pockets which may stop circulation altogether. Scale deposits will usually occur to the greatest extent in cylinder heads. Cylinder heads are frequently provided with inspection covers permitting examination when overheating is evident.

Where raw water must be used the circulation rate should be about 45 gallons per B.H.P. per hour and the water temperatures set at 100 degrees in and 110 degrees out to prevent serious scale formation and an increased amount of crankcase ventilation provided to reduce condensation which will inevitably occur at these low temperatures.

Water temperatures in oil coolers, air compressors and intercoolers should be kept under 120 degrees. This can be easily arranged when a by-pass recirculation system is installed on the gas engine. Where the by-pass system is not installed and the engine jacket is maintained at 145 degrees by regulating the quantity of raw water through the heat exchanger, then the raw water is also passed through the oil cooler, etc.

Exhaust System

Cylinder and ring wear as well as power loss, carbonization and valve burning, can be caused not only by high exhaust back pressure, over one inch of mercury, but also if the engine manufacturer's recommendations regarding size and length of exhaust piping are not followed.

Oil-Water Sludge

Closely allied with the subject of engine cooling is the question of sludge formation which is usually the result of improper temperature control. Sludge found in gas engines is usually a combination of the three general types—oil and water, oil and tar, or oil and carbon.

The water type of sludge may originate from leakage from the water jacket or at the oil cooler. When an engine is running, the oil pressure is usually greater than the water pressure in the oil cooler, preventing such leakage, but when the engine is stopped water may enter the oil system. It must also be recognized that large quantities of water are formed in the combustion process, most gases producing considerably more water than do liquid fuels. This water is ordinarily in the form of steam and if the water jacket and crankcase oil temperature are maintained over 130 degrees and if the crankcase is properly vented, condensation of water in the crankcase will not occur.

Until recently it has been rather common practice to circulate only small quantities of water through the engine, resulting in temperatures of perhaps 90 degrees in and 140 degrees out. Under such conditions cylinder distortion is probable with greater blow-by and the chance of steam in the blow-by gases condensing in the crankcase. This water is apt to emulsify and also cause rusting of the lower part of the cylinder. Any hydrogen sulfide in the gas will form sulfur dioxide in the blow-by gases; this will be dissolved in any water present to form sulfurous acid which will also cause cylinder wear. Where such difficulties are encountered an improvement in crankcase ventilation is desirable. Usually a tall standpipe from the crankcase will provide sufficient ventilation although a forced draft is sometimes necessary. Connecting the crankcase breather to the air intake of the engine is also effective in securing adequate crankcase ventilation, although positive protection must be taken to prevent crankcase explosions due to backfiring which occurs rather frequently in gas engines. Ventilating the crankcase in this manner may cause deposit formation at intake valves or ports.

Although new oils differ considerably in their ability to separate from water, the emulsifying tendency of used oils is largely dependent on the amount of contaminants in the oil; consequently, keeping the oil clean is good insurance against the formation of the oil-water type of sludge.

Oil-Tar Sludge

The second type of sludge, a mixture of oil and tar, is less frequently found in gas engines, the tarry matter usually originating in the crankcase as the result of high temperature or excessive aeration of the lubricating oil. This is the result of slow oxidation or the combining of oxygen from the air with the hydrocarbon liquid, to form a soft, sticky solid or perhaps just a heavier, more viscous liquid depending on how badly the oil is oxidized.

The conditions which accelerate the formation of this type of sludge are: An unstable oil, high temperature, and intimate contact of oil with air. To prevent this sludge formation use a stable oil, reduce oil temperatures, lessen the degree of atomization of the oil in the crankcase and prevent any unnecessary formation of thin films of oil on hot surfaces.

Linseed oil, an example of an unstable oil, oxidizes very rapidly even at atmospheric temperature when spread out in a thin film, giving oxygen an opportunity to contact the oil molecules. Straight petroleum oils do not oxidize appreciably at atmospheric temperature but under the influence of heat the hydrogen and carbon atoms tend to separate which gives an oxygen atom an opportunity to attach itself to the hydrocarbon forming a sludge particle.

Oil temperature, which is so important in connection with sludge formation (every 25 degrees Fahr., temperature rise about doubles the amount of oxidation), can be reduced in several ways: Water temperature can be lowered, more oil cooling provided, the oil sump capacity increased, or a less viscous oil used. High oil temperature may be due to a clogged oil cooler, to a hot running bearing or piston, to insufficient water cooling or to late burning of the fuel.

To lessen the degree of oil atomization which is largely due to splash from connecting rod bearings, oil pressure may be reduced, bearing clearance decreased, or a more viscous oil used.

It is, of course, impossible to eliminate the formation of thin films of oil on all unlubricated surfaces. Where hot spots exist as on the underside of pistons, either the amount of oil striking such surface should be kept to a minimum or great quantities of oil should be thrown against the hot spot. The advantages of flooding hot spots with oil are that the oil will cool the surface, none of the oil will be increased in temperature appreciably and the thick layer of oil does not present as many oil molecules to oxygen attack.

In addition to the piston, hot surfaces in gas engines sometimes occur at the lower end of the cylinder liner where full length water jackets are not employed; a hot running bearing and valve chambers adjacent to the exhaust manifold may also develop hot surfaces.

Should an engine casualty occur, such as a piston seizure or bearing failure, the oil should be drained and new oil supplied, as during the running period preceding the casualty the oil will have been badly overheated and oxidized. If the engine has not been stopped in time or if the oil is not drained, a bad crankcase sludging condition and piston and cylinder carbonization will result.

Overheating of the oil will result if the engine is not allowed to run a few minutes under part load before shutting down. The centrifuge heater should be turned off a few minutes before the centrifuge is stopped, also to prevent local overheating of the oil.

Oil-Carbon Sludge

The third type of sludge, a mixture of oil and carbon, is also occasionally found in gas engines. The carbon originates in the combustion chamber or on the upper portion of the cylinder walls from thermal decomposition of the lubricant and may be due either to incomplete combustion or to blow-by past the piston rings.

Thermal decomposition means breakdown of petroleum by temperature. Under the high temperatures encountered in the combustion chamber, fuel and lubricating oil combine with oxygen from the air to form carbon dioxide and water, but any carbonaceous material which is not oxidized or burned may stay behind in the engine. This is confirmed by analysis of deposits from the combustion chamber and top land of the piston, which deposits are found to be made up almost entirely of hard carbon and mineral matter.

Oils differ in their resistance to thermal decomposition, as is illustrated on page 118 of the October, 1939 issue of LUBRICATION.

Although the formation of free carbon and the resultant oil-carbon type of sludge can sometimes be improved by a change of the type of oil, much more can be done by proper control of operating conditions. Improper control of combustion conditions, particularly incorrect spark timing or air gas ratios can cause overheating and charring of the lubricating oil as well as incomplete combustion and deposition of carbon from the fuel. In this respect the gas engine has an advantage over either the gasoline or Diesel engine.

In the gas engine, distribution of the fuel is better than in most gasoline engines and the air/fuel ratio from cylinder to cylinder is more uniform. Being in the gaseous state more complete mixing of the fuel with air occurs in a gas engine than in the Diesel where the fuel is injected in liquid state. The clean burning fuel in the gas engine largely eliminates fuel as a source of free carbon in the lubricating oil.

In addition to checking the air/gas ratio and the spark timing when carbonization of the lubricant occurs, the engine should be tested for preignition, for blow-by, for scaled water jackets, for improper cooling water temperature control, and for carbon deposits on the inside of oil-cooled pistons. Excess oil consumption will obviously increase the formation of free carbon in the combustion chamber. Usually any increase in engine temperature, such as

that due to overload caused by leaking compression valves, accelerates the formation of free carbon. However, it is also possible that low temperatures under light loads and idling operation will cause carbon, the result of incomplete combustion, to build up in the engine rather than burn off as it does under normal engine temperatures and loads.

Other Causes of Sludge

Engineers of long experience are firmly of the opinion that the nature of the gas can contribute considerably to sludge formation, pointing out for example, that when heavier oils are used in sewer gas engines to more effectively seal the piston rings, sludge formation is appreciably reduced.

Typical examples of analysis of the three most common types of sludge are shown in Table I.

The oil-water type sludge will contain a high percentage of water, the oil-tar type will consist largely of benzine soluble asphaltic and tarry matter, while the oil-carbon type is identified by a high percentage of benzine insoluble carbonaceous material. Once the character of the sludge is established, the proper correction measures previously enumerated can be applied.

Significance of Tests on Used Oil

Viscosity and neutralization number increases indicate the degree of oxidation that has taken place in the oil, while the benzine

TABLE I

The three types of oil sludge

Sludge type	*Oil-Water*	*Oil-Tar*	*Oil-Carbon*
Typical Analysis:			
Oil	20.4	34.1	68.9
Benzine soluble	27.1	38.0	2.9
Benzine insoluble	3.7	20.3	20.1
Minerals	15.8	5.1	6.0
Water	33.0	2.5	2.1
Probable Source	Crankcase condensation	Crankcase oxidation	Combustion chamber
Corrective Measures:			
Oil characteristic required:	Cleanliness	Resistance to oxidation	Resistance to thermal decomposition.
Operating changes required:	1. Raise water and oil temperature. 2. Better crankcase ventilation.	1. Lower oil temperature. 2. Reduce blow-by.	1. Improve combustion 2. Reduce oil consumption.

The presence of certain metals, notably copper, develops a catalyzing effect, greatly accelerating oxidation and sludge formation; in fact, the use of copper tubing in crankcases is no longer considered good practice. Finely divided iron also acts catalytically when present in the oil.

Cases have also been reported of sludge formation, in gas engines driving generators, due to electrolysis.

Dust and iron from wear or rust act as nuclei for the coagulation of sludge particles or may even constitute a major portion of sludge. The presence of such materials will usually be detected in the chemical analysis of the sludge.

Determination of Sludge Type

Laboratory analysis is indispensable in determining the type of sludge. Since different types of sludge require different changes in operating conditions, it is dangerous to diagnose sludge troubles without first submitting a sample of the used oil and of the sludge, usually from the filter, to the chemist for determination of the sludge type.

soluble test (difference between benzine insoluble and naphtha insoluble) measures the amount of tarry matter in the oil. Oils which are exposed to oxidation in the laboratory also show a high percentage of benzine soluble matter and service tests have confirmed that this tarry material largely originates from crankcase oil oxidation.

The benzine insoluble test (difference between benzine insoluble and mineral content) measures the amount of hard carbonaceous matter in the oil. Oils which are exposed solely to oxidation contain little benzine insoluble material, whereas oils subjected to thermal decomposition contain a high percentage of free carbon. Service experience has also confirmed that free carbon largely originates from the combustion chamber.

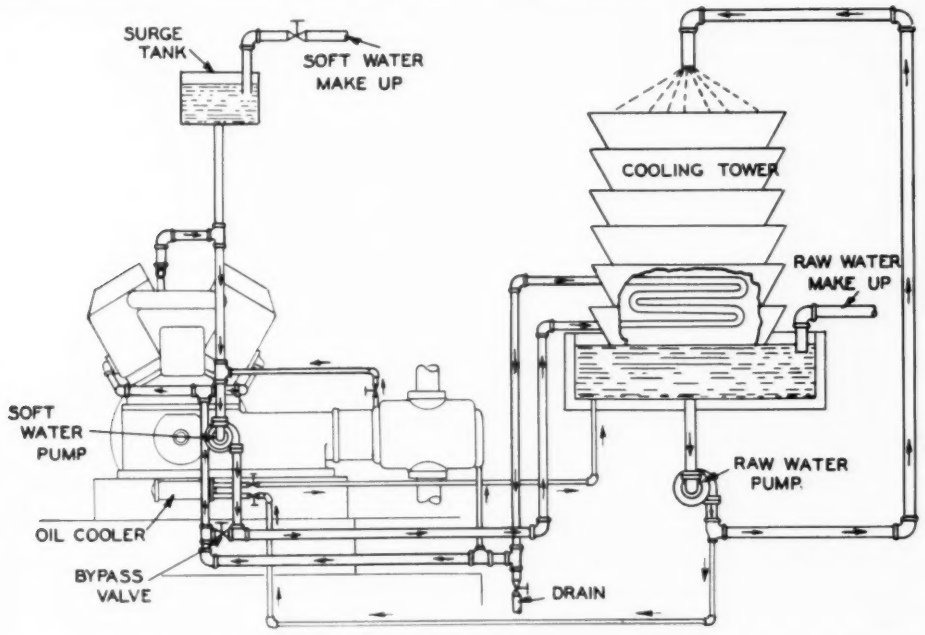
The ash test identifies any mineral matter in the oil which might cause or result from wear. Other tests determine water content, corrosiveness, etc.

In general, used oil tests indicate not only whether the oil is fit for continued use but also give a clue as to operating conditions since

any serious engine defect will usually cause a change in the condition of the used oil.

Care of Oil

Due to thermal decomposition and oxidation, as well as foreign matter contamination, solids will form in the crankcase oil at a certain rate. It is necessary to install sufficient oil purifying apparatus to remove this contamination at an equal or faster rate. Straight mineral oils permit the easy removal of carbonaceous matter and are therefore usually preferred for the gas engine crankcase since when adequately purified and barring accidents, such oils can be used for long periods in large engines. Where the oil purifying equipment is inadequate, as on many small, high-speed engines, then it is often desirable to use an oil of special dispersion ability to keep carbon particles so finely divided that they will pass through the filters, in which case the oil must be drained frequently to remove the carbon from the engine.



Courtesy of Ingersoll Rand Company

Fig. 7 Ideal Cooling System.

Bearing Examination

Bearing problems are largely of mechanical origin as an oil film will withstand pressures well above the maximum allowable bearing metal loads. An ample flow of oil is, of course, highly desirable to carry away heat from the bearing since the strength of bearing metal is greater at lower temperature. The principal consideration from the oil standpoint is cleanliness, as any sediment in the oil is apt to collect at the point where the oil enters the bearing clearance, restricting the flow of oil through the bearing.

To determine the cause of a bearing failure, examine the surface closely under a microscope. Look carefully for particles of foreign matter which might bridge the clearance between bearing and shaft, causing local over-heating. If sediment is found embedded in the bearing metal, the oil should be analyzed for contamination substances and the oil sump should be examined for foreign particles. Misalignment will be evidenced by cracks near the edge of the bearing and if suspected the crank webs should be checked; as the shaft is rotated, the distance between the webs should not vary more than .003″. If the appearance of the bearing shows that less than 85% of the area has been carrying the load, it is an indication that the bearing was improperly fitted. If the bearing metal seems to have flowed or the bearings are shelled out near the center where the load would be applied at top dead center, the engine should be checked for preignition or excessive spark advance. The back of the bearing should also be looked at to determine whether complete contact with the housing has been established. Where the shell and housing have been in contact, the surface will usually be cleaner and brighter. If the back of the bearing opposite a failed portion is dull, or coated, it is an indication that heat transfer at that point between the shell and

housing has been impaired. A bearing which is pitted over a wide area is probably corroded due to sulphur from the fuel. If the bearing metal contains a high percentage of lead or other alloys susceptible to oil corrosion, then the quality and temperature of the oil should be checked.

Exhaust Valve Sticking

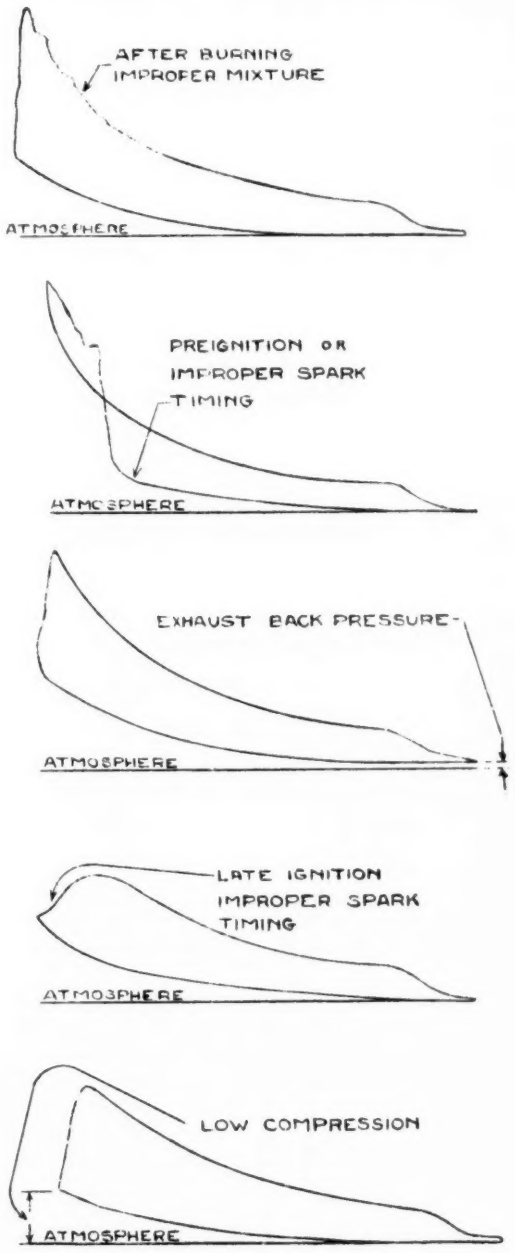
The deposits which cause valves to stick may originate from fuel, lubricant or the intake air. If the engine is equipped with an efficient air cleaner and the fuel gas is clean, then any deposits on the valve stems are usually assumed to be due to oil quality, oil quantity and valve temperature. Heavy oils of high carbon residue are to be avoided. Sufficient oil should reach the stems to provide adequate lubrication but an excess of oil will cause carbonization. If the valve stems show scuffing or other evidence of lack of oil, a light oil can be injected into the engine by the addition of an upper cylinder oiler. By far the better practice is separate lubrication of the valve stems, permitting the addition of a measured amount of the lubricant to reach the valves.

The ordinary cause of valve sticking is high temperature induced by engine overheating, by an improper seat, by incorrect spark timing air/gas ratio, or by preignition of the fuel. Valve sticking may occur if there is insufficient tappet clearance or if springs are weak; the latter can be checked by comparison with a new spring. A bell mouthed or worn guide may permit carbon accumulation as will guides which extend into the flame path.

Special Oils

Gas engines are built to run on good quality straight mineral oils. If an engine is not overloaded and is operated and serviced properly, these oils provide the most economical lubrication if efficient oil purifying apparatus is available. The special oils which have been developed recently for heavy duty internal combustion engines should be reserved for use when the engine becomes worn, overloaded or subject to some other extreme operating condition such as poor fuel. When difficulties are encountered in normal operation, the mechanical maladjustment should be corrected rather than depending on a special oil to cure the condition.

Unquestionably the special oils of high load carrying ability, greater cleansing action and other desirable characteristics should be used where advisable. On the other hand, these oils are more expensive, do not permit purifiers to remove carbon contamination, have to be drained frequently and may possess other disadvantages such as foaming and water sensitivity. When faulty lubrication is encountered, consult a lubrication engineer who has available a complete line of internal combustion engine lubricants. Some gas engines require a straight naphthene base oil; others a straight paraffin oil, and a few a special compounded lubricant, but all engines require careful, intelligent maintenance.



Courtesy of Clark Brothers Company, Inc.

Fig. 8—Significance of indicator cards.

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GAS ENGINES

ATLAS IMPERIAL DIESEL ENGINE CO.

GN141, GS528, GS1021	Ursa Oil H
GS2124, GS2771, GS2972	Ursa Oil H
GS464, GS763, GS1558, GS1964	Ursa Oil

AVIATION MFG. CO.

Lycoming AFG, ASG, AEG	Regal Oil C

BALDWIN-SOUTHWARK CORP.

De La Vergne	Ursa Oil

BRUCE-MACBETH ENGINE CO.

Type G; Others	Ursa Oil

BUTLER ENGINE & FOUNDRY CO.

Ball 12", 14", 15", 16", 17", 18"	Ursa Oil

CATERPILLAR TRACTOR CO.

3400G, 4400G, 4600G, others	Warm weather	Ursa Oil X-20
	Cold weather	Ursa Oil X-10

CHARTER GAS ENGINE CO.

Type R	Algol Oil

CHICAGO PNEUMATIC TOOL CO.

All models	Ursa Oil

CLARK BROS.

FG, RA, HS5, HS6	Ursa Oil P-30
HS: 2, 4, 7, 9, 13, 15	Ursa Oil
PC, PD, PE, PF, PB40, PB60	Ursa Oil
Bobcat, Bobkitten	Ursa Oil
Z: 4, 6, 8	Ursa Oil

CLIMAX ENGINEERING CO.

Climax G4C, H4B, N4B, R4E, R6I, R8I	Summer	Ursa Oil P-40
	Winter	Ursa Oil P-30

COOPER BESSEMER

EN, GN, JS, LSG	Ursa Oil

ENTERPRISE ENGINE CORPORATION:

A, N, R, S	Summer	Algol Oil
	Winter	Ursa Oil P-20
	Extra cold	Ursa Oil P-10
GK, GL	Summer	Algol Oil
	Winter	Ursa Oil P-20
GF, GG, GU, GW	Summer	Ursa Oil
	Winter	Ursa Oil P-30

FAIRBANKS, MORSE & CO.

46A	Algol Oil

FOOS GAS ENGINE CO.

All models	Ursa Oil

INGERSOLL-RAND CO.

XVG	Ursa Oil

THE MERIAM CO.

Below 200 HP	Algol Oil
Above 200 HP	Ursa Oil

NATIONAL SUPPLY CO.

Superior: LOC, VDMD, VDSC, VGST	Above 70° F.	Ursa Oil
	32-70° F.	Algol Oil
	Below 32° F.	Ursa Oil P-20

NATIONAL TRANSIT PUMP & MACHINE CO.

Transit 9", 24", 36"	Ursa Oil

NORDBERG MFG. CO.

Four cycle		Ursa Oil
Two cycle	Bearings	Algol Oil
	Cylinders	Ursa Oil P-40

NOVO ENGINE CO.

Novo: All models	Algol Oil

OIL WELL SUPPLY CO.

Black Bear 18", 20"	Ursa Oil

THE RATHBUN-JONES ENGINEERING CO.

Rathbun: 18", 22", 24", 28"	Ursa Oil

THE TITUSVILLE IRON WORKS CO.

Tico BL, V-10	Ursa Oil

TIPS ENGINE WORKS

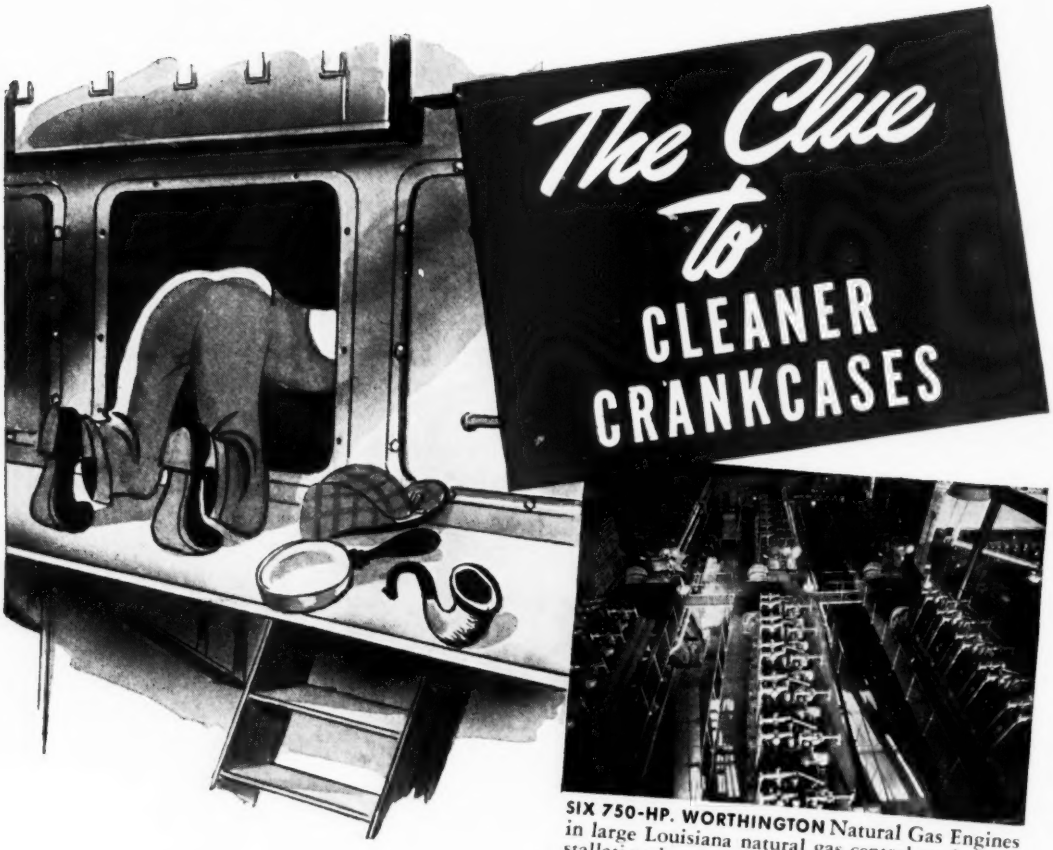
GHD	Ursa Oil

WEBER ENGINE CO.

A, AB, BM, 3BM, 4ND, 5ND, 6ND		
Mechanical Lubricator		Ursa Oil
Main Bearings—ring oiled	Summer	Algol Oil
	Winter	Alcaid Oil
Main Bearings—roller	Summer	Starfak No. 3
	Winter	Starfak No. 2
H-1, H-2, 2MC, 3MC, 4MC		
Cylinders		Ursa Oil
Bearings	Summer	Algol Oil
	Winter	Alcaid Oil
F, F-8		
Mechanical Lubricator		Ursa Oil
Main Bearings	Summer	Starfak No. 3
	Winter	Starfak No. 2

WORTHINGTON

Natural Gas Engines	Algol Oil
Sewer Gas Engines	Ursa Oil



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